Analysis of Energy-Efficiency and Urban Coverage of Sony ELTRES LPWAN as an Emerging Technology in the UK IoT Network

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***Abstract*—This paper analyses the two fundamental attributes of energy-efficiency and coverage of the ELTRES Low-Power Wide Area (LPWA) communication protocol developed by Sony as an emerging technology for the Internet of Things (IoT). The results indicate that ELTRES consumes a lower average transmission (TX) current of 7.4 mA than other UK LPWA technologies with energy efficiency per byte of 18.5 mJ and per coverage of 185 μJ/km. The simulation and coverage tests have a good agreement, showing that the urban area of Exeter, England can be sufficiently covered by a single base station, with an average RSSI of -100, -120, -135, and -140 dBm within the 1, 2, 4, and 8 km radius, respectively.**

***Keywords*—Internet of Things; LPWAN; energy consumption; coverage**

I. Introduction

The low-power wide area networks (LPWANs) sector is one of the fastest growing markets of the IoT industry with a projection to reach a global market of $ 2.5 billion by 2026 [1]. LPWANs have been in use for the past decade as a means of large coverage communication with low cost deployment in the IoT landscape; improving upon both the geographical as well as economic limitation posed by short-range wireless networks and local area networks [2]. The main characteristic difference between these technologies is LPWANs enable connection of low power and low-throughput end devices (EDs) that are distributed across a relatively large area as well as deployment or movement of said many EDs across the area, a necessity in today's application of integrated infrastructure [3].

In its development, many LPWAN technologies and protocols have emerged to accommodate the various IoT applications, one of them being ELTRES protocol developed by Sony. ELTRES is designed as an improved technology to the current key players of outdoor LPWANs such as Sigfox or LoRa, with claims of longer communication distances of 100 km and higher transmission rates between EDs and base stations [4]. In particular, as an emerging technology in the UK market, it is prudent to compare how ELTRES differentiates from key players of the UK LPWA market which are NB-IoT and LTE-M, which is by having a fixed (non-variable mode) transmission power within the communication distance and also offering only uplink (UL) data communication from EDs to the base station and no downlink (DL) [5]. Table I shows a comparative summary of ELTRES with NB-IoT and LTE-M, highlighting the key differences in the protocol. As seen from Table I, ELTRES, comparatively to LTE-M and NB-IoT, does not transmit large payload and has a relatively lower transmitter power with fewer TX repetition.

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TABLE I. Comparison of LPWAN Technologies

Technology	ELTRES [6]	NB-IoT [7]	LTE-M [7]
Standard	ETSI(UK/EU)	3GPP	3GPP
Spectrum	License-exempt band for SRD	Licensed LTE frequency bands	Licensed LTE frequency bands
TX Power	14 dBm	20–23 dBm	20–23 dBm
TX Repetition	4	Up to 128 [8]	Up to 32/2048 [8]
Modulation	UL: BPSK	UL: GFSK	UL: SC-FDMA
		DL: BPSK	DL: OFDMA, 16QAM
Bandwidth	200 kHz	200 kHz	1.4-20 MHz
Payload Size	16 bytes	1600 bytes	1000 bytes
Security	ISO/IEC 29192-2 “CLEFIA”	NSA/AES 256	AES 256
Coverage	100 km	~1 km (urban); ~10 km (rural)	~5 km
Maximum Data Rate	~ 80 bps	~ 220 kbps	~ 5 Mbps (Cat M1)
Communication Direction	One-way	Two-way	Two-way
Service Cost[a]	£ 0.51	£ 1.01 [9]	£ 1.07 [9]

a. Per device per month

As of the writing of this paper, there is no data available on the detailed current and energy efficiency as well as the coverage performance of ELTRES. Therefore, this paper attempts to identify and give knowledge by investigating the two main attributes of LPWAN technology, namely energy efficiency, and network coverage, in view of how ELTRES compares to other UK LPWAN technologies. Additionally, in a practical ED deployment, it is also often useful to have an estimate as to how long a device would last as to reduce the cost and enable consistent data delivery. As such, this report also seeks to calculate the battery lifetime based on both the payload and coverage distance variable which can be compared to NB-IoT and LTE-M to give a perspective on how ELTRES fares in the current UK LPWAN market.

II. System Description

Fig. 1 shows the flowchart of ELTRES state transition. The different stages of the state transitions are Standby, Normal (Mode 0), and DeepSleep state. Entering the normal mode (standalone operation), the Global Navigation and Satellite System (GNSS) is first used to acquire the ephemeris data (satellite orbital data) which includes height, position, time, and satellite information for geolocation and synchronization to the base station. After synchronization is achieved, the system transmits the data by means of an association request (AR) frame and data frame (DF) burst. AR and DF burst are categorical terms used by Sony to indicate the status of data transmission, with the latter being the actual payload of data transmitted. After the transmission is finished, the system will transition to either deep sleep upon which it will consume little to no current or re-acquire new ephemeris data for the next transmission. To meet the maximum 1% duty cycle set by ETSI EN 300 220-1 [10], the UK adoption of ELTRES protocol device is set to cycle every 480 seconds. The device automatically enters sleep mode after ephemeris filling where the LPWAN antenna is disabled to conserve energy until the transmission interval.

III. Experimental Work

A. Current and Energy Efficiency Measurement Setup

Analysis of the current consumption was done for the configuration of ‘Positioning Only at Startup’ for the ‘GNSS Low Power Mode’. The current measurement focuses on the GNSS parameter fetching, ephemeris filling, and TX of the Normal Mode, which are unique to ELTRES. The testing of the ELTRES protocol was done by using the ELTRES Trial Kit [4] provided by Sony, shown in Fig. 2, which includes an ELTRES development board (CXM1503GR transmitter chip; 2 V supply), multi-sensing transmitter unit (MSU) and a base station receiver which is located on the roof of the Harrison building at the University of Exeter (50°44'16.0"N 3°31'57.4"W) within an elevation height of 90 metres.

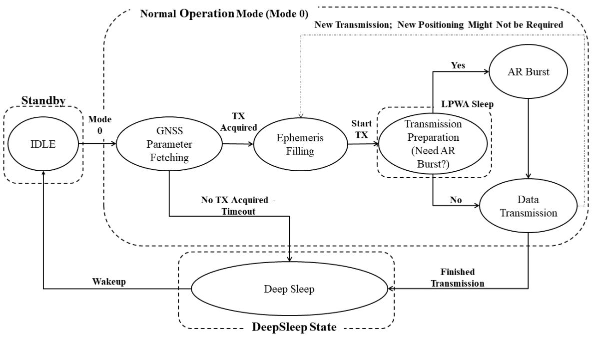

Fig. 1. ELTRES state transition

(a) (b) (c) (d)

Fig. 2. ELTRES Trial Kit: (a) development board, (b) MSU, (c) anatomy of the base station and (d) the actual base station installed on the roof

The energy efficiency per byte (EPB) and battery life estimate are analyzed to provide a fair performance comparison between the LPWAN technologies. The EPB for a given payload of data transmitted in bytes (B) can be calculated by having the average current consumption measurement (I) within the burst duration (T) and given supply voltage (V) relation stated by the following equation:

$$EPB = \frac{V \times I \times T}{B} \tag{1}$$

B. Coverage Testing Setup

The MSU provided was used to enable mobile movement transmission in outdoor applications. The measurements were done in the span of two days and the website platform ELTRES Demo App [4] was used for tracking and observing the received payload information. Data including Lfourid (MSU identification number), date, time, latitude, longitude, height, and RSSI were acquired by the website platform. The MSU device is designed to transmit data at a rate of every 10 minutes. The location of the transmission points was chosen based on the perceived uplink data based on incremental distance within the Exeter urban area. Eight notable reference points can be placed within four concentric rings for a maximum distance of eight kilometres from the base station (star symbol) as seen in Fig. 3.

TABLE II. Input Parameters for ITM Model

System Parameters	**Parameters relating to radio system**
Frequency	865 – 869 MHz
Distance	1 km to 150 km
Antenna heights	20 cm (TX) and 1.5 m (receiver)
Height from ground	1.5 m (TX) and 2.5 m (receiver)
Polarization	Vertical
Transmitter power	13 dBm
Receiver Threshold	-144 dBm
Environmental Parameters	**Statistical environment parameters**
Terrain irregularity	90 meters
Relative ground permittivity	15
Ground conductivity	0.005 Siemens per meter
Surface refractivity	301 N-units
Climate	Continental Temperate
Deployment Parameters	**Position of the radio systems**
Siting criteria	50.73778, -3.532611. (base station) Random for transmitter
Statistical Parameters	**Mode of variability of statistics**
Mode of variability	Mobile; 50%

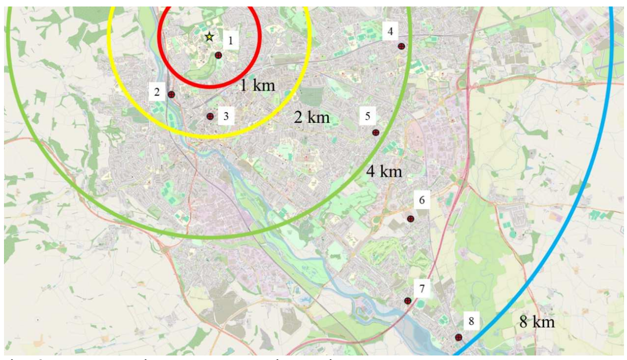

Fig. 3. Exeter main coverage testing points

TABLE III. LPWAN TECHNOLOGIES PERFORMANCE COMPARISON

LPWA Technology	ELTRES	NB-IoT [11]	LTE-M [11]
Average TX Current	7.4 mA	58.11 mA	104.85 mA
Energy per byte	18.5 mJ	13.28 mJ	4.9 mJ
Energy Efficiency (per byte per coverage radius)	185 µJ/ km	1328 µJ/ km	980 µJ/ km
Battery Lifetime (per 1 byte/ 2000 mAh)	1255 months	83 months	97 months
Battery Lifetime (per 1024 bytes/ 2000 mAh)	25 months	32 months	75 months

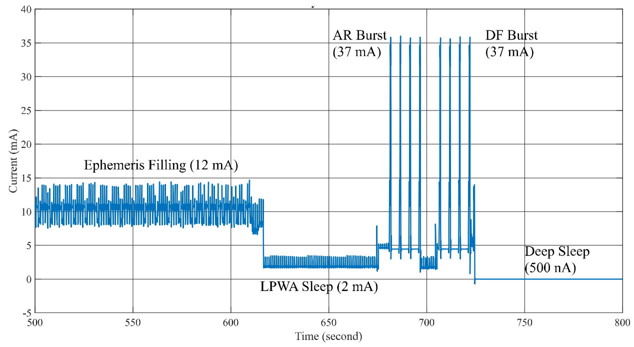

Fig. 4. ELTRES one transmission cycle current measurement

Computer coverage simulation was done using the Radio Mobile application by VE2DBE for the topographic transmission across the Exeter area. The main properties of elevation data were sourced from the Shuttle Radar Topography Mission (SRTM) earth data [12] (SRTM code: N50W004). The Radio Mobile software simulates the transmission using the Irregular Terrain Model (ITM), as to predict the attenuation of radio signals over irregular terrain such as buildings, hills, and atmospheric scattering [13]. This method was chosen as LPWA communication satisfies the 'model' condition of propagation simulation which are frequencies between 20 MHz to 20 GHz, distances between 1 to 20,000 km and height below 3 km [14]. The simulated model adopted the parameters shown in Table II.

IV. RESULTS

A. Current, Energy-Efficiency & Battery Lifetime Estimate

Fig. 4 shows the current profile of one cycle of ELTRES normal mode operation. The ephemeris filling consumes an average of 12 mA of current. The duration is highly variable, which is similar to the synchronization phase of NB-IoT [15]. It then enters LPWA sleep, which consumes 2 mA of current. The AR and DF are 10 seconds apart, lasting 20 seconds each. They have a peak current of 37 mA and an average of 7.4 mA. Finally, the system enters deep sleep, consuming 500 nA. Thus, for a 16-byte payload, the EPB is 18.5 mJ. By accounting for the effective transmission radius of 100 km, the EPB per kilometer is therefore 185 µJ/ km. Accordingly, the battery lifetime can be estimated for a real-life deployment battery capacity of 2000 mAh. Table III shows the overall performance comparison of ELTRES with other UK LPWAN technologies.

B. Coverage Simulation and On-field Test

Simulation results as shown in Fig. 5 suggest a single base station can cover most of the urban Exeter area excluding small blind spots with no line-of-sight

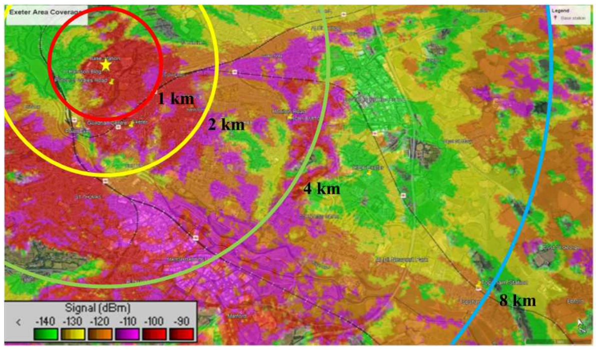

Fig. 5. Simulated coverage map for Exeter urban area; approximate radius of 8 km from base station (star)

	star	Longitude Displacement (km) 1	2	3	4	5	6
Latitude Displacement (km)	1	-100	-120	-135	-140	-145	-145
	2	-120	-105	-125	-140	-145	
	3	-125	-140	-125	-145	-140	
	4	-130	-140	-140	-140	-145	
	5		-145	-145	-135	-140	
	6					-145	-140

-100 dBm Good

-145 dBm Poor

Fig. 6. Average on-field RSSI value

communication. Fig. 6 shows the average RSSI value from the field test within the equilateral 6 km latitude and longitude displacement, totalling approximately 8 km of radius from the base station. It can be seen that as further the MSU is away from the base station, the RSSI decreases in strength. This real-life propagation characteristic shows good agreement with the simulated results. Similarly, it can be confirmed that the coverage does not degrade uniformly based on distance as the propagating signal was affected by the varying terrain and physical interference, resulting in higher RSSI in further distances, e.g., average simulated RSSI at radius band 6 km (-135 dBm) and 8 km (-122 dBm).

V. CONCLUSION

In this study, ELTRES shows a promising performance by means of a lower average TX current and best battery lifetime for small payload than both NB-IoT and LTE-M. Conversely, ELTRES has the worst energy performance per byte of data transmission, owing to the same fact of diminishing return of its small payload protocol. These results indicate that ELTRES is more suitable for large coverage and small packet size, favouring low payload ED applications with a focus on the furthest possible transmission radius and small throughput data. This study has also shown the real-life coverage capabilities of ELTRES where a single base station at an elevation of 90 meters can sufficiently cover the urban area of Exeter, averaging a signal strength of -100, -120, -135 and -140 dBm within the 1, 2, 4, and 8 km radius. Accordingly, the coverage can be improved by raising the elevation of the base station installed to theoretically achieve full coverage of the urban Exeter area, as evidenced by a similar 50 km coverage of the London area for elevation of over 300 metres by Sony's own testing [4].

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